PUTTING RESEARCH TO WORK BRIEF

Buying Time: A New Strengthening Technique for Concrete Bridges

Wisconsin roads feature over 13,000 bridges, including many rapidly deteriorating concrete spans from the 1930s and 1940s. Even 20-foot, two-lane structures can cost well over $100,000 to replace. Hence, strengthening methods such as fiber-reinforced polymer strip systems that can temporarily postpone replacement are very valuable, especially to local governments with tight budgets and many older bridges to replace.

The Wisconsin Department of Transportation measures bridge condition through inventory ratings. Based on the American Association of State Highway and Transportation Officials' H-class truck rating units, inventory ratings indicate a bridge's designed stress level adjusted for deterioration. Current standards call for bridges to be designed for a standard truck loading of HS20 or higher.

What's the Problem?

Though effective, the process of strengthening structural members with fiber-reinforced polymer strips could be improved. Conventional epoxy bonding of FRP strips is time-consuming, requiring extensive surface preparation and a curing period of at least 24 hours before the bridge can be used. Furthermore, strip detachment may lead to catastrophic brittle failure of strengthened beams and slabs. A quick means of attaching FRP strips mechanically might circumvent these problems.

Research Objectives

The goal of this research was to field-test the mechanically fastened FRP system developed at the University of Wisconsin-Madison to evaluate its potential as a rapid, cost-effective method of temporarily upgrading deteriorating bridges.

Methodology

Researchers selected a 23-foot flat-slab, reinforced concrete bridge in Edgerton over Saunders Creek. Built in 1930 to a rating of H15 and overlaid several times since, the bridge was slated for demolition and replacement. The researchers' goal was to raise the bridge's inventory rating to HS25 using the MF-FRP method. Their work included:

- Evaluating the bridge's load capacity.
- Using county maintenance crews to attach high-stiffness, prefabricated FRP strips to the bridge's concrete members with powder-actuated fasteners and expansion anchors.
- Conducting load testing after applying the FRP strips; checking for deterioration of strips or fasteners after 10 months of exposure and service; and conducting load testing to failure prior to the bridge's demolition.
- Documenting the performance of the MF-FRP system through laboratory tests.

Results

The major finding of this research was that the MF-FRP method could be used to strengthen an existing deteriorated bridge. The method is easy to use in the field, and the level of strengthening can be predicted in advance using conventional analytical methods. It offers short-term strengthening—three to five years—of bridges that are unsuitable for epoxy-bonded FRP systems. Detailed results include:

- Bridge inspection before strengthening yielded an inventory rating of HS17; the applied FRP system brought the rating to HS25. Ten months of in-service data showed the FRP strips suffered no reduction in strength. Load testing to failure confirmed that the MF-FRP system had increased the bridge's load rating.

Investigator

"With very little capital investment, this method provides temporary upgrading for those bridges that are slated to be replaced."

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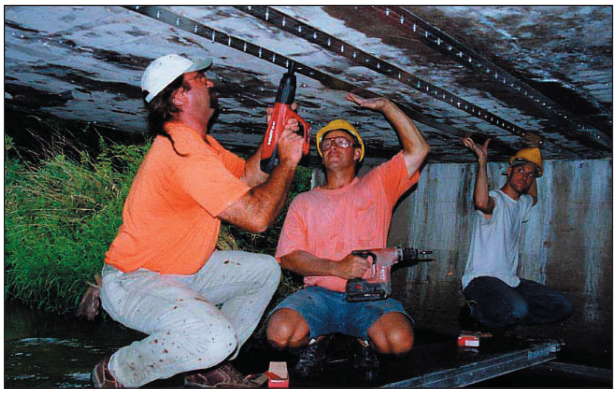
Not pictured: Michael G. Oliva, University of Wisconsin-Madison



County workers use powder-actuated fastener guns to drive steel fasteners into 4-inch-wide fiber-reinforced polymer strips (Fig. 4.21, page 45 of final report).

• Laboratory tests showed increases in yield and ultimate strength of 23% and 37%, respectively. Cyclic loading showed no significant decreases in strength or stiffness. Beams failed due to concrete compression prior to strip failing.

• Fastening required 10 to 15 minutes per strip. Including preparation, installation took 37.5 hours of labor; materials and labor cost $7,995, or $12.72 per square foot. By comparison, the cost of bridge replacement was estimated at $140,000.

Implementation

Researchers recommend that WisDOT use the MF-FRP method to upgrade the capacity of aging, structurally deficient flat-slab bridges. Specific recommendations for further training and research activities include:

• Train WisDOT engineers to design strengthening systems with FRP materials. Develop a manual outlining the use of FRP and other materials to strengthen bridges, including guidelines for matching strengthening systems to bridge types, and methods for comparing costs of alternatives.

• Investigate the suitability of the MF-FRP method for strengthening reinforced concrete girder bridges and prestressed concrete bridge girders.

• Conduct cost-benefit studies comparing bridge strengthening with MF-FRP to replacement, and comparing stainless-steel fasteners with neoprene washers to poorer-performing galvanized steel materials.

Following WisDOT's demonstration of the MF-FRP method in this study, Missouri DOT successfully applied the method to four bridges in two different counties.

Benefits

The MF-FRP system provides an affordable alternative to bridge replacement. This short-term solution to deterioration can forestall mandatory replacement, and indirectly improve bridge safety by increasing load rating. Proven successful on the flat-slab bridge in this study, the MF-FRP method may eventually be used on other types of bridges, and this research could help shape state and federal regulations and bridge management policy.

Project Manager

"The system was very efficient. It should be a benefit to communities with limited resources and needed bridge capacity for fire trucks and school buses."

–Stan Woods
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